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A STUDY OF INTEROCCLUSAL
ECCENTRIC PROTRUSIVE JAW
RELATION RECORDS

A Thesis
The Ohio State University
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⑥ A STUDY OF INTEROCCLUSAL ECCENTRIC
PROTRUSIVE JAW RELATION RECORDS,

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A Thesis

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for the Degree Master of Science

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INTRODUCTION

Opinions vary about the value of recording the inclination of the condyle path with protrusive records.^{1-26,49} Some dentists believe recording this relation is merely a waste of time;¹⁻⁴ therefore, they use the plain-line articulator technique. Others, who use an adjustable articulator technique, favor recording this relation.^{5-26,47-49}

Previous research has raised doubts about the accuracy, repeatability and usefulness of protrusive jaw relation records.^{1,30-33,44} To help determine the value of such records this study investigated the following questions:

1. Do different dentists adjust the horizontal condylar guidances of the articulator to the same setting using the same record?
2. Can several interocclusal eccentric protrusive jaw relation records of the same patient be adjusted to accurately repeat the same setting of the horizontal condylar guidances of the articulator?
3. How do protrusive records made with plaster compare to those made with wax?

4. What is the range of error if an average horizontal condylar setting is used to determine the condyle path instead of a protrusive record?

METHODS AND MATERIALS

This study was divided into two parts--one in the laboratory, the other in the clinic. In the laboratory a controlled study was made of protrusive records, using two sets of complete dentures mounted on a Dentatus ARL articulator. Records for one set of dentures were made at 6 mm. and 3 mm. of protrusion; records for the other set were made at 4 mm. and 2 mm. Six records were made for each protrusion with plaster* and six records were made for each protrusion with wax.** After the inclinations of the horizontal condylar tracks*** were adjusted to a specific setting, one plaster and one wax record were made. This process was repeated at five additional settings, as shown in Tables I to VI.

The articulator was equipped with a pin-pointed incisal guide pin. A graph was placed on the incisal table (Fig. 1). The calibrated anterior stop screws of the articulator were turned in to

*Mirrotrue impression plaster, Whip-Mix Corp., Louisville, Kentucky.

**Extra-hard baseplate wax, Dentists' Supply Co., New York.

***The condylar tracks on the Dentatus articulator³⁷ are synonymous with the condylar guidances on the Hanau articulator.³⁶

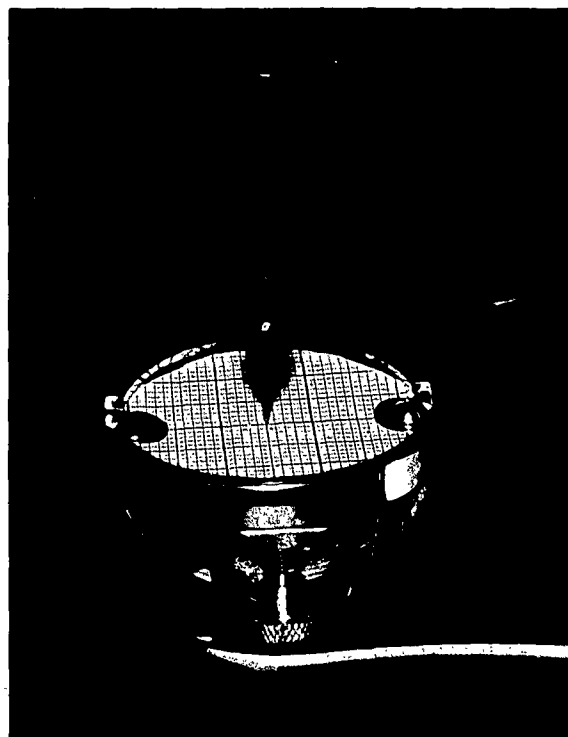


Fig. 1. Pin-pointed incisal guide pin and incisal table graph.

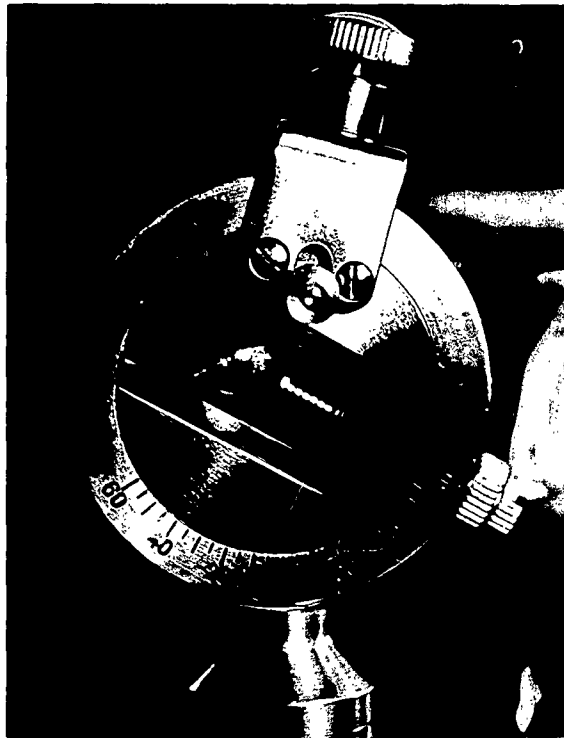


Fig. 2. Condylar mechanism adjusted for 6 mm. of protrusion.



Fig. 3. Articulator set for making a 6 mm. record.

hold the condylar spheres in the desired number of millimeters of protrusion (Fig. 2). The modified incisal guide pin was opened 2 mm. This allowed exact positional duplication for the plaster and wax records (Fig. 3).

Five dentists, graduate students in prosthodontics, adjusted each of these records once. I adjusted each record three times--first, after the second dentist, and lastly.

I computed the mean for the three adjustments of each record that I made. I also computed the mean of the single adjustments that were made by the five dentists for each record. I computed the standard deviation for each series of record adjustments using the raw score formula ($s.d. = \frac{1}{N} \sqrt{N \sum X^2 - (\sum X)^2}$). The results of this portion of the study are shown in Tables I to VI. Table VII summarizes these results.

Part Two was a clinical study of 15 subjects--10 dentulous and 5 edentulous. The dentulous subjects had at least 14 teeth in each arch, with the exception of three who had one or more fixed bridges restoring their occlusion. The edentulous subjects had well fitting complete dentures which had been constructed at The Ohio State University College of Dentistry by graduate students in prosthodontics. None of the subjects had symptoms of temporomandibular joint disturbances.

The procedure used on each dentulous subject was as follows: Three plaster* and three wax** interocclusal protrusive jaw relation records were made with the anterior teeth in an edge-to-edge relationship but not quite touching. The wax records were made using the technique advocated by Lauritzen.⁴⁷ Tin foil (0.003 inch) was cut into strips 1/8 inch wide and 3 1/2 inches long. Extra hard baseplate wax was heated in a compound heater at 140°F until thoroughly softened. A strip of tin foil was laid on the edge of a sheet of softened wax; the wax was folded around the tin foil to the desired thickness for each subject. This wax strip was cut into two equal parts, each with 1/2 inch of tin foil protruding to serve as a handle. These wax strips were then thoroughly softened in a compound heater at 140°F before they were used. A plaster interocclusal centric jaw relation record was made. Alginate impressions were made and dental stone casts poured.

The Almore hinge bow**** was used to locate the hinge axis on subjects 1, 2 and 3. The Dentatus face-bow with the orbital pointer was used to locate the arbitrary hinge axis on all the other subjects. The upper casts were then mounted on the Dentatus articulator with the hinge bow or face-bow. This placed the casts on the

****Almore Manufacturing Co., Portland 36, Oregon.

articulator in relation to the Frankfort plane. This was necessary so that the condylar inclinations of the different subjects could be compared. The lower casts were mounted on the articulator with the plaster interocclusal centric jaw relation records. Each interocclusal record was carefully trimmed to expose the buccal cusps to insure accurate adjustment (Fig. 4).

Each protrusive record was adjusted three times and the adjustments of the horizontal condylar tracks were recorded (Table VIII). The mean of the adjustments of the condylar tracks on each side for each subject were computed for the plaster records and for the wax records. The articulator was placed in the condyle track recorder (Fig. 5). Tracings were made for each subject with the condylar tracks set according to the following: the mean of the plaster records, the mean of the wax records and the average articulator setting of 40° . The deviations of the tracings of the plaster and wax records from the 40° tracing were measured in millimeters at the point that the anterior teeth were in an edge-to-edge protrusive relationship (Fig. 6). These data were recorded and compared in Tables VIII, IX and X and shown graphically in Figures 7 and 8.

The procedures for the edentulous subjects were the same as those used on the dentulous subjects with the following exceptions. The undercuts inside of their dentures were blocked out and dental

stone casts were poured in them. These casts with the complete dentures were mounted on the articulator in the same way the dentulous casts were. The data for this part of the study is also shown in Tables VIII, IX, X, and Figures 7 and 8.

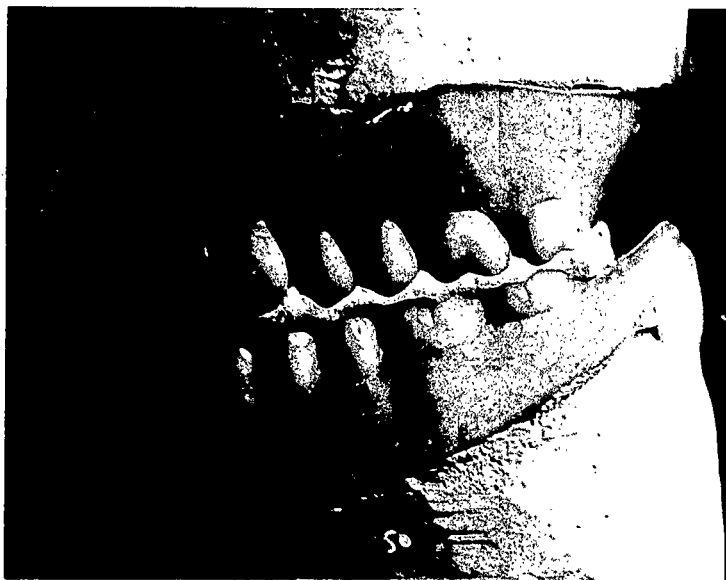


Fig. 4. Plaster record trimmed to expose buccal cusps to facilitate accurate adjustment.

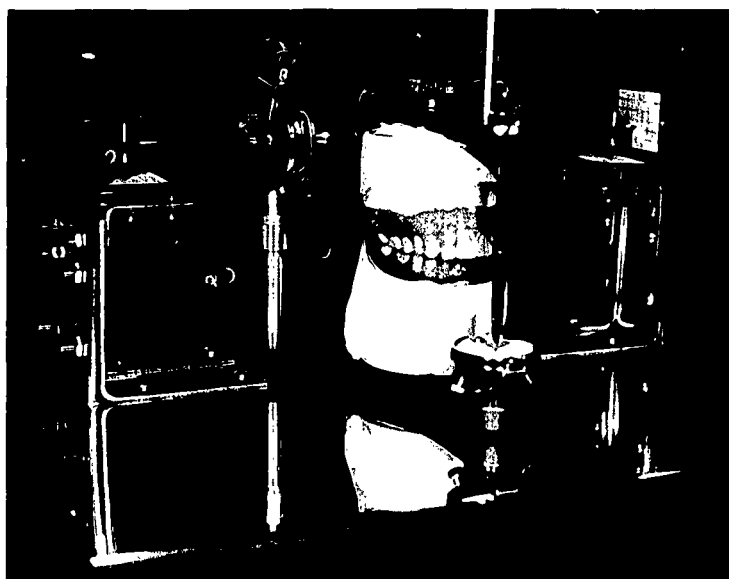


Fig. 5. Condyle track recorder.

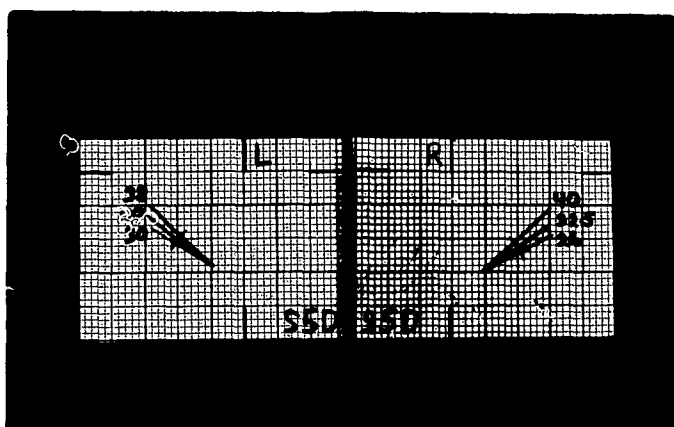


Fig. 6. Condyle track recorder graphs for subject 5D.

RESULTS

The data of part one, the controlled laboratory study, are presented in Tables I to VII. Table VII summarizes these results.

The five dentists did not adjust the horizontal condylar tracks of the articulator to the same setting using the same protrusive record. The variations in their adjustments increased as the amount of protrusion decreased.

The over-all standard deviation of the wax records, in the 4 and 6 mm. range, was greater than that of the plaster records. This difference was not consistent as shown in Tables I to VII. Therefore, from the results of part one no significant difference can be shown between the use of plaster and wax records.

The data of part two, the clinical study, are presented in Tables VIII, IX and X and in the graphs in Figures 7 and 8.

Since I mounted the dentulous casts in centric relation I felt it would be interesting to measure the number of millimeters this position was posterior to the centric occlusal position. The analyzing equipment used in this study made this easy. These measurements are shown in Table VIII for each dentulous subject. The average difference between these two positions was found to be 0.8 mm. with a range of 0 to 2.1 mm.

AMOUNT OF PROTRUSION & MATERIAL USED	AUTHOR						FIVE DENTISTS																	
	MEAN			SD			I		II		III		IV		V		MEAN		SD					
	R	L	R	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L					
6 mm. P	31	33	31.3	30.3	0.5	2.1	32.5	30	32	30	29	29	31	28	30	30	30.9	29.4	1.3	0.8				
	32	28																						
	31	30																						
6 mm. W	30	31	29.7	30.8	0.5	0.2	28	32	24.5	27.5	33	35	22	25	25	30.5	26.5	30	3.8	3.5				
	30	31																						
	29	30.5																						
3 mm. P	31	30																						
	29	31	30	30.8	0.8	0.6	30	37.5	34	32.5	19	23	24	26.5	35	39.5	28.4	31.8	6.1	6.3				
	30	31.5																						
3 mm. W	28	32	29.5	31.7	2.1	0.5	29.5	30	27	32.5	21	32	24	31	23	30	24.9	31.1	3.0	1.0				
	32.5	32																						
	28	31																						
4 mm. P	29	30	29.5	30.7	0.4	0.9	32.5	33	33	40.5	28	36	30	31.5	33.5	30.5	31.4	34.3	2.1	3.6				
	30	32																						
	29.5	30																						
4 mm. W	29	30.5	29.2	30.3	0.2	0.2	25	25	28.5	31	25	30	30	30.5	26.5	28	27	28.9	2.0	2.2				
	29	30																						
	29.5	30.5																						
2 mm. P	30	30	28.7	30	1.0	0	37	41	36	45	20	37	30	40	40	45	32.6	41.6	6.7	3.1				
	28.5	30																						
	27.5	30																						
2 mm. W	30	29	29.7	30.3	0.5	0.9	33.5	32.5	40	38	40	31	30	32	25	27	33.7	32.1	5.8	3.5				
	29	31																						
	30	31																						

Table I. 30 Degrees Protrusive Record Adjustments

AMOUNT OF PROTRUSION & MATERIAL USED	AUTHOR						FIVE DENTISTS																	
	MEAN			SD			I		II		III		IV		V		MEAN		SD					
	R	L	S	R	L	S	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
6 mm. P	5.5 6	4.5 5	5.5 6	0.4 0.4	0.4 0.4	0.4 0.4	2.5 2.5	2.5 2.5	6.5 6.5	6.5 6.5	3 3	4 4	5 5	5 5	4 4	5 5	4.5 4.5	4.5 4.5	2.5 2.5	1.3 1.3				
6 mm. W	5.5 5	5.5 5	5.5 5	0.2 0.2	0.2 0.2	0.2 0.2	5 5	6 6	3 3	4 4	9.5 9.5	1 1	0 0	6 6	6 6	6 6	4.9 4.9	5.1 5.1	2.9 2.9	3.3 3.3				
3 mm. P	5 6	6 4.5	5.2 4.5	0.6 0.6	0.6 0.6	0.6 0.6	5 5	4.5 4.5	8.5 8.5	9 9	10 10	6 6	4.5 4.5	6 6	6 6	6 6	6.8 6.8	6 6	2.1 2.1	1.7 1.7				
3 mm. W	3.5 2	4.5 4	2.5 2	0.7 0.7	0.4 0.4	0.4 0.4	-3 -3	-2 -2	3 3	7 7	-2.5 -2.5	5 5	-3 -3	2 2	4 4	10 10	-0.3 -0.3	4.4 4.4	3.1 3.1	4.1 4.1				
4 mm. P	4 5	5 4	4.3 5	0.5 0.5	0.5 0.5	0.5 0.5	10 10	10 10	6 6	8 8	2.5 2.5	4.5 4.5	8 8	10 10	10 10	22.5 22.5	7.3 7.3	11 11	2.8 2.8	6.1 6.1				
4 mm. W	5.5 5	5.5 4	5.3 5	0.2 0.2	0.7 0.7	0.2 0.2	7 7	7.5 7.5	6 6	6 6	0 0	8 8	4 4	4 4	5 5	3 3	4.4 4.4	5.7 5.7	2.4 2.4	1.9 1.9				
2 mm. P	3.5 5	5.5 6	4 5	0.7 0.7	0.9 0.9	0.7 0.7	13.5 13.5	15 15	10 10	10 10	-4 -4	4 4	16 16	12 12	5 5	22.5 22.5	8.1 8.1	12.7 12.7	6.5 6.5	6.1 6.1				
2 mm. W	4.5 5	4.5 5	5 5	0.4 0.4	0.4 0.4	0.4 0.4	5 5	5.5 5.5	6 6	3.5 3.5	2.5 2.5	4.5 4.5	13 13	1.5 1.5	11.5 11.5	17.5 17.5	7.6 7.6	6.5 6.5	4.0 4.0	5.7 5.7				

Table II. 5 Degrees Protrusive Record Adjustments

AMOUNT OF PROTRUSION & MATERIAL USED	AUTHOR						FIVE DENTISTS																	
	MEAN			SD			I		II		III		IV		V		MEAN		SD					
	R	L		R	L		R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
6 mm. P	16 16.5 15	16 15.5		0.2	0.4		15	15	15	15	14	14	14	14	18	17	15.2	15	1.5	1.1				
6 mm. W	16 16 15	15.7 15.8 15.5		0.5	0.2		12.5	13	7	8.5	12	10.5	11	13	16	13	11.7	11.6	2.9	1.8				
3 mm. P	15.5 14 17	16 16 18		1.2	0.9		19	21	18	20	18	21	12.5	19.5	32	35	19.9	23.3	6.5	5.9				
3 mm. W	12.5 13.5 14	16 19 16		0.6	1.4		12.5	13	16	17	10	10	16	15	15	20.5	13.9	15.1	2.3	3.6				
4 mm. P	16 15 15	15 15.7		0.5	0.9		26	22.5	20.5	25	16	21	22.5	20	16	19	20.2	21.5	3.9	3.6				
4 mm. W	17 15.5 16	15 16 14.5		0.6	0.6		15	14.5	14	16.5	12	16	19.5	20	17	18	15.5	17	2.6	1.9				
2 mm. P	15 15 16	17 16 15		0.5	0.8		15	25	25	28	20	20	30	21	18	27	21.6	24.2	5.3	3.2				
2 mm. W	16.5 15 15	17 15.5 16.5		0.7	0.6		18	18	17	17	17.5	16	9	17	19	20.5	16.1	17.7	3.6	1.5				

Table III. 16 Degrees Protrusive Record Adjustments

AMOUNT OF PROTRUSION & MATERIAL USED	AUTHOR				FIVE DENTISTS																							
					MEAN		SD		I		II		III		IV		V		MEAN		SD							
	R	L	P	W	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L						
6 mm. P	39	41.5			38	41.2	0.8	0.2	36	39	36	40.5	39	42	36.5	42	46	47	38.7	42.1	3.8	2.7						
	38	41.1																										
	37	41																										
6 mm. W	39	41			39	41.5	0	0.4	36	41	36	41	37	45	32.5	40	39	45	36.1	42.4	2.1	4.7						
	39	42																										
	39	42																										
3 mm. P	40	44			38.3	42.3	1.3	1.3	41	42	43	47.5	40.5	44	51	51	56	51	46.3	47.1	6.1	3.6						
	38	41																										
	37	42																										
3 mm. W	34	36			34.7	37.8	1.3	1.6	31	32	35	40	33.5	37	37.5	38	49	45	37.2	38.4	6.3	4.2						
	33.5	40																										
	36.5	37.5																										
4 mm. P	38.5	41.5			39.3	41.5	0.8	0	4.75	49	45	48.5	43	48	41	44	42	43	43.7	46.5	2.3	2.5						
	39	41.5																										
	40.5	41.5																										
4 mm. W	37	40			37.8	41.3	0.6	1.0	33	34.5	37	38	33.5	38	39	41	46.5	49.5	37.8	40.2	4.9	5.1						
	38.5	42.5																										
	38	42.5																										
2 mm. P	39	42			37.7	42.3	1.9	0.5	40	42	42.5	47	38.5	46.5	45	47.5	46	42.5	42.4	45.1	2.9	2.4						
	35	43																										
	39	42																										
2 mm. W	40	41.5			39.7	41.3	0.5	0.6	40	40.5	39.5	43	49	47	39	43	42.5	45.5	42	43.8	3.7	2.3						
	40	40.5																										
	39	42																										

Table IV. 39 Degrees Right, 41 Degrees Left Protrusive Record Adjustments

AMOUNT OF PROTRUSION & MATERIAL USED	AUTHOR												FIVE DENTISTS																							
	MEAN				SD				I				II				III				IV				V				MEAN				SD			
	R		L		R		L		R		L		R		L		R		L		R		L		R		L		R		L					
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L						
6 mm. P	45	48.5								45	48.5	45.5	50	46	50	47	51	44	49.5	45.5	49.8	1.0	0.8													
	45	50	45.3	49.2	0.5	0.6																														
	46	49																																		
	46	50																																		
6 mm. W	45.5	49.5	45.7	49.8	0.2	0.2	43	47	46	51	47	56.5	52	56.5	60	60	49.6	54.2	6.0	4.6																
	45.5	50																																		
	46	47.5																																		
	46.5	54	46.3	51.3	0.2	2.8	49	53.5	48	55	48	50.5	54	48	49	48.6	52.1	1.1	2.6																	
3 mm. P	45.5	48	45	48.8	1.1	1.1	46.5	46	41	47	48	53	39	41	53	53	45.5	48	5.0	4.6																
	43.5	48.5																																		
	46	50																																		
	46	50																																		
4 mm. P	46.5	50.5	46	50.5	0.4	0.4	53	55	51	57.5	48.5	54	52	58.5	47	54	50.3	55.8	2.2	1.9																
	45.5	51																																		
	45	48.5	45.5	48.3	1.3	0.2	44.5	44.5	43	41.5	43	47.5	48	42	45.5	44	44.8	43.9	1.9	2.7																
	45	48.5																																		
4 mm. W	42.5	55	42.5	55	1.2	1.4	45.5	63	46.5	59.5	49	59	50	55	47	60	47.6	59.3	1.7	2.6																
	42.5	53	43.3	54.8	1.2	1.4	45.5	63	46.5	59.5	49	59	50	55	47	60	47.6	59.3	1.7	2.6																
	45	56.5																																		
	46	48	47	49.8	0.8	1.3	47.5	48.5	49	48.5	45	50	53	55	28	29	44.5	46.2	8.7	8.9																
2 mm. W	46	48	47	49.8	0.8	1.3	47.5	48.5	49	48.5	45	50	53	55	28	29	44.5	46.2	8.7	8.9																
	47	50.5																																		

Table V. 46 Degrees Right, 49 Degrees Left Protrusive Record Adjustments

AMOUNT OF PROTRUSION & MATERIAL USED	AUTHOR						FIVE DENTISTS																	
	MEAN			SD			I		II		III		IV		V		MEAN		SD					
	R	L	R	R	L	R	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
6 mm. P	13.5 14 14	22 21.5 21.5	13.8 21.7	0.2	0.2	15	22.5	13.5	20.5	17	25	15	18	16	24	15.3	22	1.2	2.5					
6 mm. W	13 14.5 15.5	21 21.5 23.5	14.3	22	1.0	1.1	13	22	17.5	24	17.5	23.5	8	14	18	27	14.8	22.1	3.9	4.4				
3 mm. P	12.5 13.5 13	23 22 23	13	22.7	0.4	0.5	6.5	12	13.5	21.5	15	24	10	18.5	33	34	15.6	22	6.3	7.2				
3 mm. W	13 13 15	22 20.5 20	13.7	20.8	0.9	0.9	14	15	7.5	14	11	21	16.5	21	16.5	21	13.1	18.4	3.5	3.2				
4 mm. P	14 14 13.5	22.5 22 23	13.8	22.5	0.2	0.4	18	24	20	28	12	25	14	22.5	17.5	32	16.3	26.3	2.9	3.4				
4 mm. W	16 15 14	19.5 20 19.5	14.3	19.7	0.5	0.2	15	17.5	12.5	16	15.5	18	14	20	15.5	19	14.5	18.1	1.1	1.4				
2 mm. P	11 13.5 14.5	20 25 22.5	13	22.5	1.5	2.0	16	23	16	26	14	28	20	29	16.5	23	16.5	25.8	2.0	2.5				
2 mm. W	13.5 13 10.5	20 22 21.5	12.3	21.2	1.3	0.9	0	15	4.5	18	12	14	1	10	10	11	5.5	13.6	4.8	2.9				

Table VI. 14 Degrees Right, 21 Degrees Left Protrusive Record Adjustments

			AUTHOR.		FIVE DENTISTS					
			MEAN °		S.D.		MEAN °		S.D.	
			R	L	R	L	R	L	R	L
I. 30°	6 & 4 mm.	All	29.7	30.6	0.8	0.7	29.4	32.4	3.8	3.0
			29.9	30.5	0.4	0.9	29	30.7	2.3	2.5
		P	30.4	30.5	0.4	1.5	31.2	31.9	1.7	2.2
		W	29.5	30.6	0.4	0.2	26.8	29.5	2.9	2.8
II. 5°	6 & 4 mm.	All	4.6	4.9	0.5	0.5	5.4	7	3.3	3.8
			5.1	4.9	0.3	0.5	5.3	6.6	2.7	3.2
		P	4.9	4.9	0.4	0.4	5.9	7.3	2.7	3.7
		W	5.3	4.9	0.2	0.6	4.7	5.4	2.7	2.7
III. 16°	6 & 4 mm.	All	15.4	16	0.6	0.8	16.8	18.2	3.6	2.8
			16	15.6	0.5	0.6	15.7	16.3	2.7	2.1
		P	16	15.6	0.4	0.7	17.7	18.3	2.7	2.4
		W	16	15.5	0.6	0.4	13.6	14.3	2.7	1.9
IV. 39°R, 41°L	6 & 4 mm.	All	38.1	41.2	0.9	0.7	40.5	43.2	4.0	3.4
			38.5	41.4	0.6	0.4	39.1	42.8	3.3	3.7
		P	38.7	41.4	0.7	0.1	41.2	44.3	3.1	2.6
		W	38.4	41.4	0.3	0.7	37	41.3	3.5	4.9
V. 46°R, 49°L	6 & 4 mm.	All	45.5	50.3	0.7	1.0	47.1	51.2	3.4	3.6
			45.6	49.5	0.6	0.4	47.6	50.9	2.8	2.5
		P	45.7	49.9	0.4	0.5	47.9	52.8	1.2	1.3
		W	45.6	49.1	0.8	0.2	47.2	49.1	3.9	3.7
VI. 14°R, 21°L	6 & 4 mm.	All	13.5	21.6	0.8	0.8	14	21.4	3.2	3.4
			14.1	21.5	0.5	0.5	15.2	22.1	2.3	2.9
		P	13.8	22.1	0.2	0.3	15.8	24.2	2.0	2.9
		W	14.3	20.9	0.8	0.7	14.7	20.1	2.5	2.9
S.D. Part I					0.7	0.7			3.6	3.3
	All	6 & 4 mm.			0.4	0.5			2.7	2.9
	All	"	P		0.4	0.6			2.2	2.5
	All	"	W		0.5	0.5			3.2	3.1

Table VII. Summary of Protrusive Record Adjustments

The amount of protrusion to allow the anterior teeth to meet edge-to-edge is listed for each subject in Table VIII. The average for the ten dentulous subjects was 5 mm. The average for the five edentulous subjects was 5.4 mm. The average protrusion for all of the subjects was 5.2 mm.

The adjustment of three interocclusal protrusive jaw relation records of the same subject could not be adjusted to accurately repeat the exact same setting of the horizontal condylar guides of the articulator. The maximum variations from the smallest adjustment of one record to the largest adjustment of another record in the three record series for each subject are listed in Table IX. The variations between these records were greater for the edentulous than the dentulous subjects. The plaster records for seven subjects and the wax records for five subjects were within the error of the articulator adjustment. The error in the adjustment of the articulator was not calculated in this study because of the many variables affecting it. (See Discussion). The error that Posselt^{30,31} reported for the Dentatus articulator (4.6° rounded off to 5°) was used for this determination.

The condylar inclinations recorded with the plaster records differed significantly from most of those recorded with wax records. They differed on the right side from -1.3° to -21.4° and on the left side from 4° to a -14.7° . It was interesting to note that the

maximum variations on the right side both occurred in the dentulous subjects; while the maximum variations on the left side both occurred in the edentulous subjects.

The average condylar inclinations for the subjects in this study recorded with plaster records were 39.3° on the right side and 38.2° on the left side. The average condylar inclinations with plaster records for the dentulous subjects were 41.3° on the right side and 40.4° on the left side. The average condylar inclinations of the edentulous subjects with plaster records were 35.4° on the right side and 33.7° on the left side. The average condylar inclinations recorded with wax records were 30.1° on the right side and 32.6° on the left side. The average condylar inclinations for the dentulous subjects with wax records were 33.9° on the right side and 33.8° on the left side. The average condylar inclinations with wax records for the edentulous subjects were 22.6° on the right side and 30.1° on the left side.

The mean plaster and mean wax record for each subject varied from the average 40° articulator adjustment. These differences are shown in Table X and Figures 7 and 8. The maximum variations recorded with the plaster records were 15.8° to -12.8° on the right side and 11.6° to -12.1° on the left side. The maximum variations recorded with the wax records were 11.4° to -35.1° on the right side and 8.1° to -20.7° on the left side.

	MM. C. R. POSTERIOR TO C. O.	MM. PROTRUSION	RECORD NUMBER	PLASTER		MM. DEVIATION OF INCISAL GUIDE PIN	WAX		MM. DEVIATION OF INCISAL GUIDE PIN
				R	L		R	L	
1D	0.	4	I	46	47	0.5 R	40	38.5	0
				47.5	47		41	38	
				46	48		40	38	
			II	44	48	1.75 R	39	40.5	0.5 R
				43	48		40.5	40	
				43	47.5		41	39.5	
			III	48	60	0	40	38	0
				50	59		38.5	38.5	
				49	60		38.5	38	
2D	1	3	I	48	52	0	48	48	3 L
				49	52		47	47	
				50	52		50	49	
			II	50	53	1 L	46.5	46.5	1 L
				48	52		48.5	49	
				48.5	52.5		49.5	50	
			III	51	49	2.5 L	47.5	48	2 L
				49	50.5		47	46	
				50	49		48	48	
3D	2.1	5	I	56.5	49.5	0.5 L	51.5	46.5	2.75 L
				56.5	50		52	44	
				56	49.5		52	45	
			II	54.5	46	2.5 R	51.5	45.5	2 L
				56	46.5		51	46	
				56	46.5		51	46	
			III	55	48	2 L	51.5	43	0.25 L
				56	48		51.5	43.5	
				56	48		51	42.5	
4D	0.5	4	I	32	40.5	0	31	23	0
				32.5	38.5		31	23	
				32	38.5		32	22	
			II	32	39	0.5 L	28	21.5	1 L
				32	38.5		29	25	
				32.5	38		28	26	
			III	32	34	0.5 L	30	29	0
				32	34		30	28	
				32	35.5		30	27.5	
5D	0.75	5	I	35	43	0.5 L	28	30	2.5 R
				35	44		32	36	
				36	44		29.5	30.5	
			II	35	43	0	24	28	1 L
				36	43.5		27	32	
				36.5	42.5		27	30	
			III	36.5	42	0.5 R	28	36	0
				33	38		24	28	
				32.5	38		26	30	

	MM. C. R. POSTERIOR TO C. O.	MM. PROTRUSION	RECORD NUMBER	PLASTER		MM. DEVIATION OF INCISAL GUIDE PIN		WAX		MM. DEVIATION OF INCISAL GUIDE PIN
				R	L			R	L	
6D	1	5.5	I	34	36			36	31	
				33	35	1	R	35	32	2 L
				33	35			34	30	
			II	40.5	34			38	30	
				41	35	0.75	R	38	31	0
				40.5	35			37.5	30	
			III	41	35			38	31	
				41	34	0		37.5	31.5	0.25 R
				40	34			37	32	
7D	0.75	3.25	I	44	45			39	44	
				42.5	44	1	L	39.5	45	0.5 L
				42.5	43.5			38	43	
			II	41	41.5			37.5	42.5	
				40	40	1	L	38	45	0.5 R
				40	41.5			36	44	
			III	45	43			34	40	
				45	43	1	L	35	39	0
				44	42.5			36	41	
8D	1	5	I	37	31.5			18	19.5	
				36.5	31.5	1	L	16	20	2 L
				37	31			18	19.5	
			II	35	29			16.5	28	
				35	27.5	2.25	L	17	28	2 L
				36	28.5			18	28	
			III	37.5	21			23	21	
				38	27	1	L	24	22	0.5 L
				37	30.5			24.5	22	
9D	0.5	6.5	I	38	26.5			12.5	16	
				38	27	2.5	L	12	16	2.2 L
				38	26			12.5	15	
			II	43	29			19	20.5	
				42.5	28	2	L	21	19	0.25 L
				43	29			22.5	21.5	
			III	40.5	29			24	23	
				38.5	28.5	2	L	22.5	21	2.1 L
				40.5	28.5			23	21.5	
10D	0.75	9.2	I	39.5	38			34	39	
				38	38.5	1	L	32	38	2 L
				38	38			32.5	37.5	
			II	38.5	40			30	33.5	
				38	40.5	1	L	29	32.5	1.5 L
				38	39.5			28	32	
			III	34	36.5			27.5	32	
				34	37	1	L	28.5	32.5	1 L
				33.5	37			28	33	

	MM. C. R. POSTERIOR TO C. O.	MM. PROTRUSION	RECORD NUMBER	PLASTER		MM. DEVIATION OF INCISAL GUIDE PIN	WAX		MM. DEVIATION OF INCISAL GUIDE PIN
				R	L		R	L	
1E	5		I	22.5	26	1 L	2	31	4.5 L
				21	26		5	32	
				20	28		0	31	
			II	30	38	5.5 L	25	38	1.25 L
				31.5	39		21	36	
				32	38.5		24	38	
			III	29	37.5	1 L	15	35	1 L
				29.5	37		15	36	
				29	38		16	36	
2E	5		I	22	27	3 R	5	29.5	2 R
				22	27		5.5	30	
				22	27		5	30	
			II	20	32	1 L	4	31	1 L
				20	32		4	32	
				20	32		3	32	
			III	2.5	17	1.5 R	6	30	1.75 L
				3	18		6	29	
				3.5	17.5		6	30	
3E	5.25		I	39	33.5	2.75R	27	32.5	1.5 R
				39	35		27.5	33	
				39	35		27.5	34	
			II	37.5	49	2.5 R	25	36	2.5 R
				37.5	49.5		23	36	
				37.5	49.5		24	37	
			III	39	47.5	1.75R	30.5	39.5	0.5 R
				38	47.5		30	39	
				38.5	47.5		30	39	
4E	8		I	46	28	2 L	27.5	25	1 R
				46	29		28	24	
				46	29		27	24	
			II	36.5	21	1 L	29	27.5	4 L
				37	20.5		30	28	
				36	20.5		29	27.5	
			III	29.5	11	2 L	31	21.5	2 L
				30	12		30.5	21	
				30	12		30.5	21	
5E	3.75		I	50	37	1 R	27.5	24.5	2.5 R
				50.5	37.5		30	25.5	
				51	37		27	24	
			II	52.5	37	0.5 R	41.5	30	2.75 R
				51	42		42	30.5	
				50	42.5		41.5	30.5	
			III	57.5	44	2 R	27.5	23	2 R
				57	44		27.5	23.5	
				58	44.5		28	22.5	

Table VIII. Data for the Clinical Subjects

	PLASTER		WAX	
	R	L	R	L
1D	7	13	2.5	2.5
2	3	4	3.5	4
3	2.5	4	1	4
4	0.5	6.5	4	7.5
5	1.5	2	5.5	8
6	8	2	4	2
7	5	5	5.5	6
8	3	4	8	8.5
9	5	3	12	8
10	6	4	5	7
1E	11.5	12.5	25	7
2	2	5	3	3
3	1.5	16	7.5	7
4	16.5	18	4	7
5	8	7.5	14	8

Table IX. Maximum Variations from the Smallest Setting of One Record to the Largest Setting of Another Record for Each Subject.

The condylar inclination on one side influenced the actual path of movement of the condylar track on the other side. When a condylar inclination was steeper on one side than the other the effective path of protrusive movement was tipped. The graphs of seven subjects illustrated this by tracing a path of a lower inclination higher than one of a steeper inclination. (See Figure 6 for subject 5D. The tipping of the effective protrusive path caused an inclination of 38° to trace a steeper path than one of 40° .)

The variation of the protrusive records was measured in millimeters from the average 40° setting at the point that the anterior teeth were in an edge-to-edge protrusion. These measurements were made on the graphs that had been traced for each subject on the condyle track recorder. These measurements, although very small and subject to error, presented an approximation of the amount of error that could occur in the occlusion. They are listed in Table X.

ID	MEAN FOR PLASTER RECORDS		MEAN FOR WAX RECORDS		Degrees Difference Wax Mean From Plaster Mean		Degrees Difference Plaster Means from 40°		Degrees Difference Wax Means From 40°		mm, Difference from 40° Tracing			
	R	L	R	L	R	L	R	L	R	L	PLASTER		WAX	
1D	46.3	51.6	39.8	38.8	-6.5	-12.8	6.3	11.6	-0.2	-1.2	0.4	1.3	-0.1	-0.1
2	49.3	51.3	48	48.1	-1.3	-3.2	9.3	11.3	8	8.1	0.6	0.5	0.4	0.4
3	55.8	48	51.4	44.7	-4.4	-3.3	15.8	8	11.4	4.7	2.3	0.1	1.5	-0.1
4	32	37.4	29.9	25	-2.1	-12.1	-8.9	2.6	-10.1	-15	-0.8	um	-0.5	-1.6
5	35.1	42	27.3	31.2	-7.8	-10.8	-4.9	-2.6	-12.7	-8.8	0.6	-0.8	-0.6	-1.5
6	38.2	34.8	36.8	30.9	-1.4	-10.9	-1.8	5.2	-3.2	-9.1	0.3	-0.8	um	-1.7
7	42.7	42.7	37	42.6	-5.6	-0.1	-2.7	2.7	-3	2.6	um	um	0.3	0.3
8	36.5	30.1	19.7	23.1	-16.8	7	-3.5	-9.9	-20.3	-16.9	um	-1.7	-2.7	-1.9
9	40.2	27.9	18.8	13.3	-21.4	-8.6	0.2	-12.1	-21.2	-20.7	0.9	-2.9	-2.7	-2.3
10	36.8	38.3	29.9	34.4	-6.9	-3.9	-3.2	-1.7	-10.1	-5.6	-0.7	um	-2.4	-0.4
1E	27.2	34.2	19.3	33.4	-7.9	-0.8	-12.8	-5.8	-20.7	-6.6	-2.5	-0.3	-4.3	-0.4
2	21	29.5	14.9	30.4	-16.1	0.9	-19	-10.5	-35.1	-9.6	-4	-0.8	-7.7	1.2
3	36.3	43.7	27.2	36.2	-11.1	-7.5	-1.7	3.7	-12.8	-3.8	-0.5	-0.7	-1.9	0.1
4	37.3	20.4	29.2	24.4	-8.3	4	-2.5	-19.6	-10.8	-15.6	0.8	-3.6	-0.8	-2.2
5	51.1	40.6	32.5	25.9	-20.6	-14.7	13.1	0.6	-7.5	-14.1	1.7	-0.6	-0.3	-1.7
MEAN T	39.3	38.2	30.1	32.6										
MEAN D	41.3	40.4	33.9	33.8										
MEAN E	35.4	33.7	22.6	30.1										

Table X. Comparison of the Mean Clinical Results

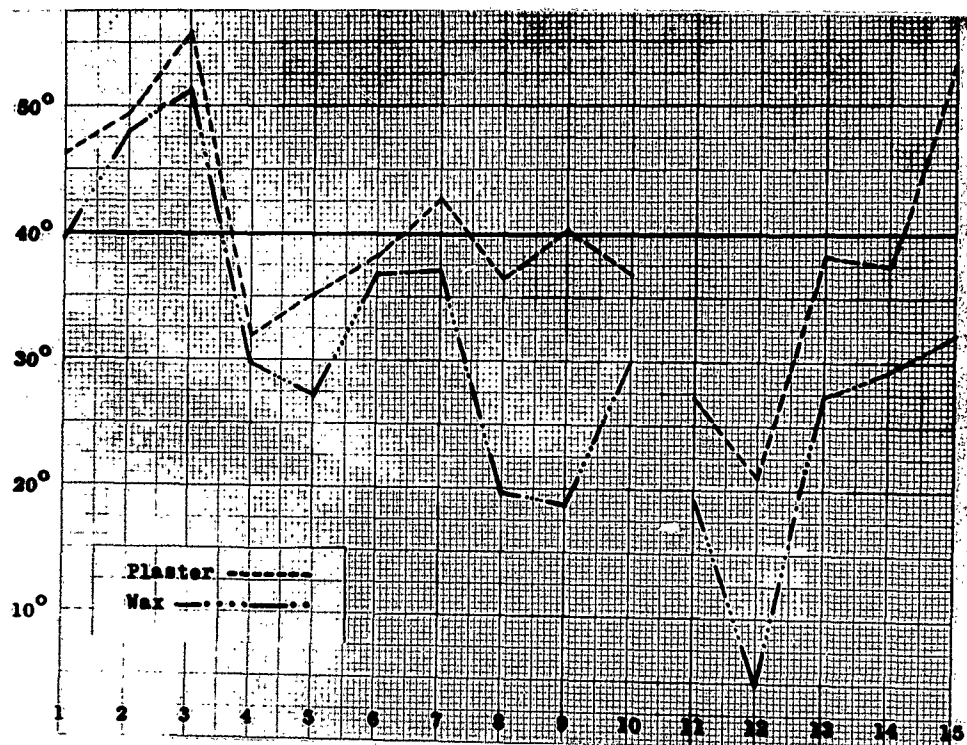


Fig. 7. The mean condylar inclinations of the clinical subjects--right side.



Fig. 8. The mean condylar inclinations of the clinical subjects--left side.

DISCUSSION

The variations in the condylar paths of different subjects and frequently on opposite sides of the same person point out a need for recording these relations. These facts are stressed in many prosthodontic textbooks.²⁰⁻²⁵ Christensen²⁶ was the first to report a lowering of the mandible in the molar area during protrusion due to the inclinations of the paths of the condyles (Christensen phenomenon). It is this change in position that allows us to record condylar inclinations with interocclusal protrusive jaw relation records. Whether the recording of the condyle path is worthwhile or not due to the shortness of the path during function requires further investigation.

Craddock¹ studied the use of protrusive interocclusal jaw relation records on three dentulous subjects. He used wax records made at various amounts of protrusion with and without biting pressure. He tried to correlate the positions of the condyles in the Glenoid Fossae with protrusive jaw relationships. He felt, as many other dentists,^{6,12,29} that the protrusive record should be made with the anterior teeth in an edge-to-edge relationship.

He concluded that this amount of protrusion was usually insufficient for accurate adjustment of the condylar guidances of the articulator. Therefore, he felt that the use of protrusive records were merely a waste of time.

Posselt and Franzen³⁰ reported on Nevakari's study of seven subjects using protrusive interocclusal wax records to record condyle path inclinations. The registrations and the readings were also done by a second dentist. Nevakari found the variation between the results of the two dentists to be too large to be of any value. He therefore felt that wax records were unreliable for recording condylar inclinations.

Posselt and Franzen³⁰ made a comparison study to Craddock's.¹ They obtained a smaller standard deviation than Craddock had. The only difference between their two methods was that Craddock had mounted the casts for his study in centric occlusion on a Hanau H articulator. Posselt and Franzen mounted their casts in centric relation and oriented them to the Frankfort plane on a Dentatus ARL articulator. Posselt and Franzen felt that the differences in their results were due to using the retruded position and possibly greater care in the handling of delicate wax records.

I agree with Posselt and Franzen that the small difference in the mounting positions probably had little effect in the results, but I agree with them also that it might have. Studies have shown

that in 90 per cent of adults centric relation is 1 mm. posterior to centric occlusion.^{27,28} Centric relation for the subjects in my study averaged 0.8 mm. posterior to centric occlusion, with a range of 0-2.1 mm. Adding a millimeter or so to the protrusive relation on the articulator will increase the ability and accuracy to adjust the condylar inclinations. The accuracy of the adjustment of protrusive records to record condylar inclinations increases as the amount of protrusion increases. This has been demonstrated in this study and in many others.

Posselt and Nevstedt³¹ studied the condyle path inclinations of 101 dentulous subjects. Dental students recorded these relations with wax records under the supervision of instructors. They observed a variation between 0 and 60°. The condylar inclinations of most of their subjects were in the 40 to 50° range in relation to the Frankfort plane. The average inclination was 39.1° on the right side and 40.4° on the left side. They felt that the condyle path should be recorded when a patient has a condylar inclination over 49° or under 31°. They found this to occur in 50 per cent of the subjects. Since the condyle path would have to be recorded to find out whether the patient was average or not, this indeed seems to indicate that the condylar inclination should be recorded.

Posselt and Franzen³⁰ compared the condyle path inclination obtained by five different dentists and found a difference of 5°. They felt that this small difference was due to the considerable experience of these dentists with this technique. Each of these dentists had adjusted the record three times and the mean and standard deviation was calculated for each. The average standard deviation for the five dentists was 3.6, with a range of 1.8 to 4.8. They did not mention the amount of protrusion at which this record was made. The average standard deviation for all the records in part one of my study adjusted by five dentists were 3.6 on the right side and 3.3 on the left.

The difference in the record adjustments of the author and the five dentists in this study were mainly due to technique. Poor adaptation of the record to the dentures by the adjusting dentist caused some of the large variations in the 6 and 4 mm. records. The varied hand position of the five dentists was another variable. None of the five used exactly the same hand position each time to hold the upper member of the articulator. I did, however, notice that when the hand holding the upper member of the articulator into the record was placed anterior to the dentures the inclinations recorded were usually of a higher value. When the hand was placed posterior to the mounted dentures, the adjustments recorded were usually of a lower value. Dentist III most often held the record

in position on the dentures by holding the bottom tip of the slightly raised incisal guide pin in his fingers. His results could never be predicted. Dentist V usually used the method of adjustment recommended in the Dentatus Articulator Instruction Book.³⁷ None of the five dentists made effective use of their tactile sense.

Posselt³⁴ recommends placing four fingers on the upper mounting ring and exerting pressure over the middle of the casts to feel when the upper cast is resting evenly in the protrusive record. This is an excellent suggestion. It allows the use of tactile sense to feel the correct adjustment in addition to just looking to see the accurate adaptation of the record to the casts or dentures on the articulator. The Hanau Articulator Instruction Book³⁶ suggests that.... "one hand might be placed on the upper member to exert slight pressure to sense the satisfactory seating." Boucher³⁵ recommends placing the fingers of one hand on top of the articulator on the mounting screw to feel when the record is correctly adjusted. He⁴⁶ also recommends looking through a magnifying glass to observe the accurate adaptation of the protrusive record to the dentures or casts on an articulator.

The Dentatus ARL articulator was selected for this study because of its similarity to the popular Hanau articulator and its previous use in similar research.

Posselt^{30,31} reported an error of plus or minus 2.3° in the adjustment of the horizontal condylar tracks of a Dentatus ARL articulator. I observed a similar error in the adjustment of the Dentatus ARL articulator that was used in this study. I found that there were a couple of degrees of movement, depending upon the amount of protrusion, during which I could observe no change in the accurate appearing adaptation of the record to the dentures. This movement was greater with small amounts of protrusion and became smaller with increased amounts of protrusion. Because of this variability I did not attempt to measure this error. I felt that it would differ in other articulators and even in the same one that I used due to friction, wear, tolerance and how the articulator was handled. I tried to adjust the condylar tracks of the articulator to the center of this area of movement without looking at the condylar inclination markings. I adjusted each side separately, then rechecked the adjustment of each side again to improve the accuracy of the adjustment. I attribute this technique to the production of the small standard deviations of the records that I adjusted.

Therefore, I believe a better understanding of the limitations and handling of the articulator could decrease the variation in adjustments by different dentists. The horizontal condylar guidances of a Hanau type articulator should be adjusted to the highest point of movement to keep the condylar spheres in direct contact with the

lower tracks. The horizontal condylar guidances of an arcon type articulator should be adjusted to the lowest point of movement to keep the condylar spheres in direct contact with the upper tracks.

The differences shown between the plaster and wax records in this study require further investigation. Swenson²² stated some reasons for these differences. "The registration will vary according to the biting pressure exerted after the mandible has been protruded. The greater the biting pressure, the flatter will be the path. If taken in wax (intraoral), it will depend on how soft the wax is at the time of registration. When it is registered with soft plaster, the inclination obtained is usually steeper." The fact that biting pressure will flatten the inclination was demonstrated by record number III of subject 2E. One pin-point tooth contact on the right side was believed to change the path about 18° on that side and 13° on the other side.

Possible factors accounting for the difference between the plaster and wax records in this study are resiliency of the wax, uneven hardening of the wax,⁴⁸ and changes in muscle tension as the record sets. I believe the difference was due mainly to a very slightly more resistance of the wax than the plaster. I had asked the subjects about this. Most of them noticed no difference between the plaster and wax closing resistance. A few thought there might have been a slight difference. Further research is recommended to learn the answer to these problems.

Posselt and Nevstedt³¹ reported that they are not completely convinced about the amount of difference in the condyle path which other authors report as being insignificant. Craddock,¹ feels that a change of 10° changes the posterior occlusion only 0.5 mm. in the second molar area. Marolt³¹ pointed out that it requires 15° to make this change. Nevakari³¹ reports a change of 0.5 mm. or less for 96 per cent from an average of 45° . Hanau⁴⁹ felt that the maximum tolerance was 0.1 mm. but does not tell how he came to this conclusion.


According to Craddock¹ the error in the occlusion at the second molar would be one-half of the values listed in Table X. He made this statement because he felt that the second molar is located half way between the condylar and incisal guidances. Of course this will vary with the position in the articulator that the casts or dentures are mounted. My results in Table X differed from Craddock's in most instances. The tipping of the effective protrusive path, as explained before, may be the reason for this difference.

Studies have also been made on the type of articulator design and how it effects protrusive movements.^{30,38-45} The results of some of these studies have been somewhat conflicting.

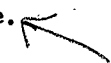
It certainly appears that this and most previous studies favor the recording of the condylar inclinations. Of course this could be

because most of those who do not record it do not bother to mention it. The big unanswered question appears to be whether the condyle path is long enough during function to record it accurately or not.

SUMMARY AND CONCLUSIONS

 This study investigated ~~several~~ aspects of interocclusal eccentric protrusive jaw relation records ^{were studied} to help clarify the value of their use. The findings of this study were:

~~1.~~ ^{1.} The ~~five~~ ^{five} dentists did not adjust the horizontal condylar tracks of the articulator to the same setting using the same protrusive record. Although there were differences in the adjustments of these records, the variations were not great enough to be able to say that protrusive records are worthless. The variations tended to increase as the amount of protrusion decreased. A better understanding of the limitations and handling of the articulator could decrease the variation in adjustments by difference dentists.

~~2.~~ ^{2.} The adjustment of several protrusive interocclusal eccentric jaw relation records of the same subject did not accurately repeat the same setting of the horizontal condylar tracks of the articulator. The variations that did occur were believed to be due to error in the adjustment of the articulator, differences in position and possibly to muscle tensions while the records were being made. 

3. In part one no significant difference could be shown between the adjustment of plaster and wax records. In part two almost all of the plaster records produced a steeper inclination than the wax records. Further research is suggested to clarify the reasons for this difference.

4. Although the findings presented here are not conclusive they indicate some reasons for recording condylar inclinations with protrusive records. Further research is necessary.

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